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14. ABSTRACT

Armstar, Phase II, has used COTS information technology and tools to tackle problems associated with the delivery of healthcare in rural/remote environments. Four tasks were undertaken as follows: 1) Develop a working prototype to convert "care-critical" information on paper medical charts into an electronic format; 2) Evaluate tele-healthcare technology to address provider shortages in remote areas; 3) Evaluate the use of PDA's by EMS personnel in the field; 4) Develop a web-accessible physical information portal.

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ACMH Armstar

Armstrong County Memorial Hospital

Care-Critical Information at your Fingertips

Rural/Navy Health Deployed Records
Armstar Phase II
Armstrong County Memorial Hospital

Final Technical Report

December 29, 2003

Submitted by:
Dianne Emminger, Principle Investigator
Vice President Information Services
Armstrong County Memorial Hospital
One Nolte Drive
Kittanning, PA 16201
(724) 543-8480
emmingerd@acmh.org

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Armstar Background and Objectives

The Armstar model is founded on a belief that health status, outcomes, and costs will be improved through better access to information and that access to information can be improved with innovative uses of information technology.

The rural community, with its long distance from and limited access to healthcare resources, presents many healthcare delivery challenges that drive up the cost of providing quality services. This mirrors many of the healthcare delivery challenges found in the Navy deployed forces environment. With ACMH, a non-profit community hospital located in central Armstrong County in Western Pennsylvania, as the hub, the rural community is ideal as a test bed for the development of an affordable civilian/military community health information communication system in its more manageable number of linkages than might be found in more complex urban environments. Information technology which can be successfully employed in the rural healthcare delivery system to overcome resource shortages and improve collaboration among providers can be successfully used to improve the quality and reduce the cost of healthcare provided to deployed armed forces units and their dependents. The Armstar model positions the rural community hospital as a collaboration hub that electronically connects smaller healthcare providers to other networks and enables information sharing and establishes the utility of commercial off the shelf technology (COTS) to provide low-cost interfaces to clinical users.

The Armstar project began in 1996 by ACMH and independent practitioners, and our first accomplishment was to develop a secure and flexible network infrastructure extending to the far reaches of Armstrong County for the purpose of bringing healthcare information to authorized providers. Our collective goal has been to use tele-health technology and healthcare informatics to overcome many barriers to access and increase the quantity and quality of healthcare services rural clinicians are able to provide.

The project has been designed as four major phases to insure that the technology acquired and developed in each phase will survive regardless of the funding of any future phase.

Phase I – the infrastructure

The first phase of the project was to develop a repository of hospital information and make it available to independent practitioners serving the same population of patients. The repository contains test results, consultative reports, history and physical reports, operative reports, medication lists, allergies and diagnoses. Fire walls and secure identification methodologies have been implemented to assure that only authorized users have access to the data while simplifying access by the user-friendliness of a web

browser. ACMH has recruited experienced network engineers and healthcare informatics personnel to manage and support this system for the benefit of the patients and providers in Armstrong County.

Phase II - the integration of healthcare information

The second phase of the project, the subject of this report, has focused on the development of a common portal to integrate access to the hospital repository, radiology images and care-critical primary care information. A picture archival and retrieval system (PACS) has been implemented and integrated with an evolving electronic medical record. Software has been developed to facilitate the capture of care-critical information from legacy (paper) medical records. An integration engine has been programmed to take advantage of all ANSI and HL7 standards to facilitate the transmission of data from one system to another. The infrastructure is sufficiently developed to support research regarding user interfaces and their impact on care delivery.

Phase II – add-on – to begin February 2004.

In this add-on phase, requirements identified in Phase II will be folded into the model and improve our ability to conduct further field tests. The activities planned are: 1) the development and deployment of patient access cards that contain links to care-critical information; 2) completion of Phase II field testing; 3) the development of an information link to remote trauma centers for care critical information from the ACMH repository and the records of its medical staff; 4) the expansion of PACS to include Computed Radiography CR capability for non-digital radiology modalities; 5) completion of the network to include information technology aimed at reducing the potential for medical errors.

Phase III – portability and technology transfer -10/1/2004 – 12/31/2005

To validate the broad applicability and portability of the Armstar technology and to assess the magnitude of potential cost savings, we will implement the Armstar model of connectivity in another Western Pennsylvania community, conduct a needs assessment for integration with major healthcare networks and implement the trauma link developed in the Phase II add-on.

Phase IV – integration with major healthcare networks – 1/1/2005 – 9/30/2006

In this phase we plan to connect the two Armstar networks with other major public and private healthcare networks.

Our Continuing Role as a Demonstration Site for Tele-health Technology

Throughout all phases, the Armstar Network is being used as a demonstration site to determine the usefulness of telehealth technology and information sharing in addressing the problems of access in the rural/remote environment.

In Phase II we specifically set out to determine how comprehensive electronic medical records have to be to be useful throughout the continuum of providers and whether the technology can be made easy enough to use that it becomes a practical tool to clinicians. Phase II can be summarized as a set of four tasks as follows:

1) We developed a working hardware and software prototype to convert health records only available on paper into an electronic format that can be shared among providers.
2) We implemented and evaluated remote access technology for two healthcare service areas that are typically underserved in rural/remote communities.
3) We field tested personal digital assistant devices, PDA's, to determine if they interfere with emergency medical treatment services when used by EMT personnel at the emergency care site or en-route to a hospital.
4) We implemented integration technology and developed a common information portal for access to disparate software and hardware systems at the clinicians' desktops.

This report details the activities, findings, and the most likely path forward for each task.

TASK 1
ABSTRACTING LEGACY PATIENT RECORDS INTO ELECTRONIC MEDICAL RECORDS MANAGEMENT SYSTEMS

Objective:

Find a low-cost process to convert unformatted, handwritten medical records into pieces of discrete healthcare information that can be integrated into any electronic record.

As the field of primary health care begins to embrace the use of computers for clinical documentation, the facility of these information systems is limited by the need for historical information found only in paper charts. As deployed armed forces units and their dependents move from community to community over time and seek the services of healthcare providers within those communities, they carry their charts with them. But even though the complete medical history is in the charts, there is increased risk of missed diagnoses and likelihood that services will be duplicated because the time available for new physicians to review those handwritten charts is limited.

Approach and Scope:

We developed an electronic template, integrated with several types of low-cost data capture technology, to guide medically competent individuals in the process of abstracting discreet information from scanned images of paper records. To minimize the costs to develop the working prototype of this Clinical Data Architecture (CDA) and most quickly bring it to field testing, we limited the information to be abstracted to information that is considered "care critical" in emergency situations. We contracted with the Pennsylvania State University, Applied Research Laboratory, to perform this task.

Deliverables:

1) Define "care-critical" patient information.
2) Analyze the current state of the art technology.
3) Decide the format of "care critical" patient information and design the database schema.
4) Develop a working prototype for field tests.

Results:

1) Define "care-critical" patient information: In order to define the elements of care critical patient information, physicians of different specialties supplied a list of what they considered the "care-critical" information. From these lists, the investigators compiled a composite list to determine the chart extractions that were identified consistently by the physicians and the number of times they appeared in the physicians' lists. Emergency department and primary care physicians then met with

the project investigators to discuss the compiled information and agree upon the critical patient information.

2) Analyze the current state of the art technology. We learned that there are numerous potential technologies currently or soon to be available that have the potential to satisfy the necessary functional requirements for abstracting legacy patient records into electronic medical records. These include optical character recognition, intelligent character recognition, handwriting recognition, voice recognition, eye/body movement detection, and natural language processing. Due to this wide range of options, the investigative team applied specific criteria, including accuracy of results, increased productivity, user friendliness and cost to the technologies evaluated. Using web searches, conference attendance, company representative discussions, and application of the team's significant experience in the area, six software and hardware technologies were selected for initial investigation. This research revealed that no single technology satisfies all the requirements for efficiently converting paper medical records into electronic form. However, keyboard entry, voice recognition, handwriting recognition, and optical character recognition in combination appear to have the potential to provide a realistic and practical solution for this challenge. The team decided to use HL7 standard software for transmitting medical information between computerized systems and as the standard for storing the electronic medical record abstracted from the paper medical records. The State Of The Art Technology Report is attached as Appendix A.

3) Decide the format of care-critical patient information and design the database schema: The format of critical patient information is driven by two requirements, the logical categories of critical patient information as arranged by the medical providers and the order and arrangement of information as handled by the provider's automated patient record system if one is available. This format became the basis of a design template for critical patient information. The logical categories were identified during the process of defining "care critical" patient information. In an effort to complete the second requirement, the investigative team met with staff from Penn State Geisinger Health System to learn how they approached paper record conversion and what lessons were learned. This resulted in the development, review, and modification of a paper format that eventually became the design template for the electronic format. The database schema design is attached as Appendix B.

4) Develop a working prototype for field-testing: A user interface for field trials has been developed that integrates the template, an electronic archive, a thesaurus, and digital transcription system with an electronic repository. A user shell has been configured to allow for experimental connectivity to the Armstar integrated healthcare information network. The team anticipates having one medical provider participate in a field test for approximately three months, February – April 2004. A technology overview of this prototype is attached as Appendix C.

Summary of Findings:

Given the constraints of designing an efficient, low-cost system, we found no single user interface worked well in all circumstances. Because our prototype had to be designed to accommodate records from any provider, we could make no assumptions about the legibility or physical conditions of the documents. We found that technology capable of the fastest data conversion was least able to maintain consistent accuracy when the qualities of the documents were poor. The greater need for human intervention actually lengthened the time required for the process. We also learned that variations in processes cause one technology to be favored over another. For example, a clinician practice utilizing the system to convert all records to an electronic format prior to implementation of an EMR had different requirements than a practice desiring to convert records one at a time as patients were scheduled for new appointments. We found that it was necessary to provide several options for data collection and abstraction allowing the end user to determine the appropriate balance between collection speed and detail of abstraction. The prototype specification was designed with the flexibility to substitute one interface for another on demand during the abstraction process.

Although the design flexibility required a variety of input devices we were still able to design the entire system so that equipment costs would total less than $10,000. And in spite of the variability of document quality, researchers conducting laboratory tests of the system were able to complete the abstraction process in an average of 15 minutes per chart once they became competent in the technology use. The prototype description is provided in Appendix C.

Path Forward:

Field tests of the prototype will be conducted between February and April 2004. The results of field tests, which will better define how users envision the overall system functioning, will be incorporated into a second-generation system designed for operational field testing in multiple medical offices with real-time connections to the Armstar integrated healthcare information network. The design of the Armstar model, however, presents concerns that must be overcome before the technology is implemented in the "live" environment.

The Armstar repository is not designed to duplicate or replace individual providers' records. It is designed to facilitate the aggregation and integration of those records. To include records that are not in any electronic format requires that the host organization, in this case ACMH, provide storage for the information. Certain healthcare information is static, the dates of and reasons for past hospital admissions or surgical procedures. Other information is dynamic such as a patient's list of current medications. Static information requires adequate storage capability to allow information to accumulate. Dynamic information must be kept current. These challenges will be addressed in Phase II add-on.

In Phase III, following the development of processes to address the concerns and the completion of the second-generation system, research subjects will be solicited for the purpose of assessing the usefulness, completion and accuracy of the healthcare information. Participants will authorize the abstracting of their "care-critical" healthcare

information into the repository and will consent to a conditional release of that information to healthcare providers participating in the research. In this phase, we will introduce a wallet-size healthcare information card that contains the location of the network hub that hosts the "care critical" information and the access key.

TASK II

DEMONSTRATE THE USE OF INFORMATION TECHNOLOGY TO IMPROVE ACCESS TO HEALTHCARE SPECIALISTS

Objective:

Evaluate how remote access to healthcare information can increase the productivity of specialists when serving rural communities. We selected wound healing for homebound patients and radiological image interpretation as our areas of focus.

In rural areas, as in many of the areas where military personnel are deployed, specialists are often not available. These professionals are generally located in highly populated urban areas where their demand is strong. Distance, a lack of transportation systems, and rural geographic conditions impede travel by patients to those urban areas. We believe that computer technology and healthcare informatics can be used to mitigate those shortages.

Interest in such technology has grown dramatically in recent years, with an estimated 50-fold utilization increase in telemedicine during the 1990s in the United States. But the healthcare industry's use of remote access to information still lags far behind others due to a lack of resources and legal, cultural, and social barriers. We hope that our successful demonstrations, along with those in other communities, will help prove the value of the technology and break through the barriers.

Wound Care - Approach and scope:

In the area of wound care for homebound patients, we equipped ACMH home health nurses and aides with digital cameras to photograph patient wounds, such as pressure ulcers or other chronic wounds. ACMH contracted with a software vendor to store the images on line with related documentation. The software used for the trial was WoundExpert. The records were made available to physicians and personnel at the ACMH wound healing center.

Wound Care – Deliverables and Findings:

From October 2001 through March 2002, we gathered base-line data as followed:

- Annual home health patients treated – 1156.
- Annual visits by homecare nurses or aides – 16,460.
- Number of patients treated with wounds – 58.
- Annual visits for wound care – 926.

This baseline data shows that an average of 16 visits are required for the wound patient. The average for all patients, including wound patients, is 14.24. We postulated that telemedicine could be used to improve the collaboration among patients, primary care physicians, and wound care specialists, to reduce the average time interval between

evaluation and treatment intervention. This would result in fewer average visits for wound care, a reduction in cost.

In November 2002, the investigative team purchased digital cameras to be piloted. Home health nurses were trained to use these cameras in conjunction with their laptops used to document patient care. Home health patients who failed to respond to traditional wound treatment methods had their wounds photographed by the home health nurses using the digital cameras. These images were then transmitted to the WoundExpert database, making the images viewable by primary care physicians or wound care specialists who would make a recommendation regarding the clinical plan for that patient.

We found that the improved technology did little to facilitate access to wound care specialists because the specialists were often not available at the time home care personnel were visiting the patient. The team tried scheduling wound care visits to coincide with times that wound healing personnel were available but the nature of the rural geographic environment made clinician arrival times unreliable. As a result, only five consultations were facilitated with wound healing personnel, not enough to form any conclusions.

Nevertheless, we found that we were still able to reduce the number of visits for wound care patients. Post implementation data shows we were able to accommodate 762 visits for 165 wound care patients. This is a marked decrease from 16 visits per patient to 4.6 visits per patient--an improvement factor of four. We have attributed this improvement to closer coordination between the home health nurse and the primary care physician.

Remote Radiology – Approach and scope:

To provide remote access to radiological images, we implemented Picture Archiving and Communications System (PACS) technology and integrated it with the Armstar repository. The specific PACS was selected based upon its ability to provide image-viewing software that runs on common desktop computer systems. While future plans include the integration of images associated with other clinical disciplines such as cardiology and obstetrics, we limited PACS images to radiology in this phase

Remote Radiology – Deliverables and Findings:

In May 2002, a committee comprised of radiologists, information service staff, technologists, and hospital administrators was formed to conduct a needs assessment and determine selection criteria for a PACS. In addition to cost and benefits, criteria were developed to address facility requirements, teleradiology (remote) requirements and the ability to integrate the PACS with the Armstar repository. The PACS committee created a formal Request for Proposal (RFP) for purchase, implementation, and ongoing support/maintenance of an integrated PACS solution. Five vendors responded to the RFP and provided on-site demonstrations. Visits to imaging facilities using the systems were arranged for the two systems evaluated most highly by the committee. DR Systems

PACS was chosen because it was the most cost efficient and provided the best fit with the Armstar goals.

The Thomas Group, Ltd. was contracted to facilitate the selection and implementation of PACS. A summary report, prepared by Dale Hunt of the Thomas Group, is attached as Appendix E.

At ACMH, the range of case turn around time for radio logic studies improved from 1-5 hours before PACS to 0-1 hours after PACS. Additionally, film expense decreased by $2780 per week. Film printing was reduced by $1244 per week.

<u>Path Forward:</u>
We will expand PACS to include images from other healthcare disciplines and will continue to act as a test bed for telemedicine trials.

TASK III
VALIDATING WIRELESS HAND-HELD ELECTRONIC DEVICES ASSISTING EMERGENCY MEDICAL FIELD PERSONNEL

Objective:

Determine whether paramedics can utilize electronic devices (PDA's) to collect clinical and demographic data before arriving at a hospital emergency department. We wanted to ascertain whether the devices interfere with the care of the patient.

Approach and Scope:

Through a partnership with the Pennsylvania State University Applied Research Laboratory and Armstrong County EMS personnel we conducted a field demonstration to investigate the usefulness and validate the benefits and/or failures of handheld electronic devices, called personal digital assistants (PDA's). Paramedics from 5 volunteer hose companies covering all of the ACMH service area participated in the project. We observed how and when the data was collected, the device ease of use, and the perceived benefit to EMS personnel.

Task Deliverables:

1) Develop/acquire the software application for the PDA that is effective in collecting the data.
2) Develop/acquire a database management infrastructure:
3) Demonstrate the application in field use and make modifications as necessary.

Results:

1) Develop/acquire the software application for the PDA. EMS and ER personnel were involved in the decision to select EMStat, a desktop patient reporting system and REMStat, PDA software developed by Med-Media, Inc. The only modification required was the incorporating of the names of ACMH physicians and the customizing of some drop down menus to reflect ACMH information

2) Develop/acquire the database management infrastructure. The cellular communication coverage north of ACMH is "spotty" at best due to the area being sparsely populated. Consequently, wirelessly communicating data to the ER was not possible. In light of this, no ER database management infrastructure was required to support this phase of the project. This problem was easily mitigated. Upon arrival at the ER, EMS personnel print the patient data via the infrared port providing the ER Doctor with the patient information collected in the field.

   The EMStat system provided the infrastructure to populate individual repositories residing at each hose company. All five EMS services directly populate their

patient care information database exclusively by electronic means using the PDA's.

Demonstrate the application in field use: Four EMS services, Dayton, Kittanning, Ford City, and Sugar Creek, have been involved in field use since January 2003. Startup at a fifth service, Worthington, was delayed due to personnel changes after a county election. All five are now documenting paramedic care daily using the PDA's. Some statistics on PDA use per month are:

- Dayton – 50
- Kittanning – 300
- Ford City – 150
- Sugar Creek – 80

Findings:

There have been minor adjustments made to the PDA's, such as re-installation of software, but no major challenges have surfaced. All five services report very positive feedback using the PDA's.

Some data is entered into the PDA via a keyboard or by using "Graffiti" handwriting inherent in the PDA. En route to the emergency room, EMS personnel also input patient data such as assessment information, medications given, etc., into the PDA's by checking off boxes that offer specific information. This greatly reduces the risk of entering incorrect information. Once at the ER, they print from the PDA via the infrared port to the emergency room printer a record for use by the ER staff. That report is incorporated into the patient's ER chart.

Additionally, the PDA software allows EMS personnel to complete the Pennsylvania EMS Report, required by the state of Pennsylvania, electronically using a "Hot Sync" feature. This method reduces dependency on memory, the burden of administrative/reporting tasks, and the "down time" between answering calls, increasing available field time to attend to patients. The EMStat system provides a valuable tool to extrapolate information from the trip reports, such as time of heaviest response, call severity and most frequent day of the week response.

Path Forward:
In Armstar Phase III, the performance improvements documented in Phase II will be confirmed for EMTs in surrounding rural communities.

TASK IV
EXPANSION OF THE HEALTHCARE INFORMATION NETWORK, SYNCHRONIZATION OF THE DESKTOP APPLICATIONS, PORTAL AND INTERFACE DEVELOPMENT

Objective:

Show that disparate systems, even when owned by independent organizations, can be integrated at the desktop and that such integration will increase clinical access to the remote applications.

Background:

Maintaining a degree of both patient choice and professional autonomy within a healthcare system calls for the efficient transfer of patient information to and from authorized providers of services. Recent studies have shown that computer technologies can improve collaboration among healthcare providers in the areas of efficiency, frequency, and democratic dialogue.

Preventive and primary healthcare in rural communities is mostly provided by independent practitioners. Many of these providers lack both the financial and technical resources to acquire and support electronic patient record systems. The clinical information systems that are acquired by some do not readily interface with the systems of others. Most communication of healthcare information in rural/remote areas is via paper.

It is our belief that the rural community hospital, often the largest provider with the most resources, should function as a collaboration hub to enable electronic health information transfer among independent practitioners. In Phase I of this project, ACMH was positioned as that hub within Armstrong County, making hospital information available to physicians in their offices and developing interfaces and mapping tables that logically integrate disparate information systems. In this task, the work completed in Phase I has been expanded upon in order to fully demonstrate the utilization of the technologies acquired and developed in tasks I-III within this report.

Task Deliverables:

1) Developed and implemented robust and standardized integration methodologies.
2) Contracted with legacy system vendors to retrofit systems currently being used by ACMH to support the Armstar information repository.
3) Developed a web-enabled physician information portal (PIP) that includes an authentication repository with custom linkages for access and two-factor authentication to protect patient privacy and network reliability.

Progress:

1) Developed and implemented robust and standardized integration methodology:

   In January 2003, a Task I team member attended the HL7 Working Group meeting. HL7 is a medical industry standard for moving medical information from one place to another. This meeting enabled the member to learn the fundamentals of the Health Level Seven (HL7) standard and analyze what parts of the standard could be applied to the ARMSTAR project. On return, he evaluated the HL7 Clinical Document Architecture (CDA) with other team members and determined that the CDA satisfies the requirement capturing historical medical record information in a structure that can be read by humans and processed by machine.

   A second team member attended the May 2003 HL7 Working Group meeting to learn how to develop applications that produce medical records in the CDA format. The team has since written Java code to produce CDAs in compliance with the HL7 standard.

   Other team members implemented the HL7 transmission structure in the interfaces developed to link the disparate information systems. An integration engine was acquired in Armstar Phase I and is maintained/supported by ACMH with non-federal funds. It has been a key component of the Armstar infrastructure and is the platform used to eliminate the need for point-to-point interfaces.

2) Contracted with legacy system vendors to retrofit systems currently being used by ACMH to support the Armstar information repository:

   The patient information repository, Patient View, an HBOC product was replaced with the Meditech Client Server Electronic Medical Record (EMR) in January 2003, supporting a more comprehensive array of data objects. Transcribed reports, such as histories and physicals and operative reports were added to the database of lab and radiology results. Technology to support clinical data trending was added. Electronic signature capability was added along with the capability of remote order entry. These activities were funded by ACMH and utilized no federal funds.

   Radiological images were not physically added to the repository but logically added. The EMR invokes an image viewer and fetches the images from the PACS to provide access to primary care providers and specialists through the common information portal. This technology is being tested at the time of this writing.

4) <u>Developed a web-enabled physician information portal (PIP) that includes an authentication repository with custom linkages for access and two-factor authentication to protect patient privacy and network reliability.</u>

   Single sign-on HIPAA compliant access to the Physician Information Portal (PIP) was accomplished using a Cisco Secure Access Server which houses user names, passwords, and access lists for all users using the PIP. Profiles, at various levels, were developed for each classification of user, thereby maximizing the ease of use and augmenting the application level security. Profiles classify data as either clinical or demographic. Patient episodes are classified as normal confidentiality vs. heightened confidentiality, which require special authorization for release. The profiles also limit the breadth of access to data. Access policies, where possible, were based upon the "need to know" rather than the "right to know."

   A position paper describing ACMH methods of protecting personal health information is attached as Appendix F.

   A network schematic is attached as Appendix G.

<u>Path Forward</u>

In Armstar Phase III, the Physician Information Portal (PIP) capability will be universally used throughout Armstrong County and transitioned to another rural community. PIP will serve as the interface for accessing the "hub" for remote "care-critical" patient information transfer.

Appendix A

ARMSTAR Phase II
State of the Art Technology Report

April 11, 2003

Prepared for: Dianne Emminger
Armstrong County Memorial Hospital
Chief Information Officer

Contract: 20F20-FFT2002, Task 1.1.2

Prepared by: Bob Ceschini and Bob Walter
Penn State University / Applied Research Laboratory
Applied Enterprise Systems Department

Purpose

Physicians need affordable and streamlined process to migrate critical patient information from legacy, paper-based patient records into an electronic format that is compatible with information technology that can be successfully employed in the rural healthcare delivery system to overcome resource shortages and improve collaboration among service providers.

This document summarizes the first step in satisfying this requirement – evaluating state of the art technologies – defined in the statement of work as:

> "Analyze the current state of the art for automatically extracting data from paper-based records as it applies to this challenge. The technology search will not be limited to the healthcare industry."

The ARL team investigates computing, software, human interfaces and information standards technologies in this report.

Background

Armstrong County Memorial Hospital provided 40 medical records to the ARL team representative of the information that needs to be converted from paper-based to electronic form. The medical records do not have a consistent structure, order or content and there are several formats for recording the same information. All records have handwritten notes with the expected wide variations in legibility. Many records have ambiguous entries in form fields, such as a list of checkboxes with checkmarks in between, that can frequently be resolved by a person reading additional information on the form.

Criteria for Technology Candidates

Though there are many, many potential technologies currently or soon to be available to satisfy the functional requirements, the team applied the criteria below to the technologies evaluated.

- Physicians must be confident in the accuracy of the results.
- New technology must collectively increase productivity over manual data entry into electronic health record systems.
- New technology must be presented in a simple and intuitive user interface.
- Software and hardware technologies must be affordable for rural physicians (less than $10,000 total) when commercialized.
- New technologies should require little physical space, i.e., do not require a separate room or closet for computers, scanners and storage.
- End-user training time must be in hours, not days.
- Solutions must maximize use of open standards.
- Solutions should incorporate commercially available tools that allow developers to customize their implementation.

The ARL team evaluated technologies candidates by conducting web searches, attending conferences, participating in webinars and speaking with company representatives. The

team also brings forward experience from prior research conducted with related technologies.

Hardware and Software Technologies Investigated

ARL/PSU engineers investigate six software and hardware technologies summarized below against the criteria above.

Optical Character Recognition

Summary

There are two general classes of OCR technologies. At the simplest level, an OCR form recognition software package is used to scan form-based medical documents that have consistent structure and machine typed information. Most software packages look for "zones" on a preprinted form and save the information scanned from those zones into predefined data structures or fields in a table in a database. There are useful variations of this technology such as scanning a form for predefined graphical elements like a mark from rubber stamp and then scanning for hand written information within it. Finally, technologies are evolving to handle unstructured forms that are forms with standard content but not the same structure, such as invoice forms from different vendors.

Maturity and Suitability

OCR is relatively mature when compared to the other technologies assessed in this report. New products from companies such as ScanSoft are full featured and affordable. However, there is no consistency in the forms in the sample medical records we have evaluated thus limiting the utility of OCR technology for this project. The technology could be suitable for one practice that uses the same forms consistently, however, it may not be suitable for multiple practices using different forms and following different procedures.

Intelligent Character Recognition

Summary

Intelligent Character Recognition (ICR) is similar to optical character recognition (OCR) but is focused on converting handwriting to data. It can be used in combination with OCR in form processing.

Maturity and Suitability

Like OCR, ICR is mature when compared to the other technologies assessed in this report. Today commercial products still only perform well with handprint isolated in predefined form fields, not unstructured notes such as those found in medical records.

Hand Writing Recognition

Summary

There are many technologies available for entering information into computers using handwriting and the degree of flexibility is limited by computing power. Computing

platforms with minimal computing power, such as the Palm Pilot, require handwriting to be well defined and structured. In late 2002, Microsoft and hardware vendors introduced Tablet PCs running the Windows XP Tablet operating system that use natural handwriting (both print and cursive) for data input. The Tablet PCs are typically powered by Pentium III (or similar) 1GHz processors, have 256MB or more of RAM, and have 10"-12" displays.

The Tablet PCs contain digitizers that overlay the LCD screens and create an electromagnetic field. When the special Tablet PC pen contacts the screen's electromagnetic field, the pen's motion translates on the screen to a series of data points. As the user moves the pen across the screen, a digitizer uses a sampling process to collect the pen's movement information. The digitizer can sample 130 data points per second. The data points that the digitizer samples are then rendered on screen as pen strokes. Because the sampling rate is so high, the Tablet PC can display and store the digital ink with a high graphical resolution, which contributes to on-screen legibility and maximizes the accuracy of the handwriting recognition process.

The technology underlying real time handwriting recognition in Windows XP tablet is Hidden Markov Models (HMMs). HMMs are stochastic models that can deal effectively with pattern variation and noise, and have successfully been applied to the modeling of time varying dynamic patterns as in the case of speech and on-line handwriting recognition. During recent years, HMMs have also been applied to the recognition of off-line cursive script, however the results have been less successful due to the difficulty of producing a consistent sequence of feature vectors from the input word image.

Maturity and Suitability

Although Palm Pilots and PocketPCs have been available and stable for years they do not have the computing power or the display size required for this project. Tablet PCs are relatively new packaging and integration of existing technologies and appear to be promising for this project. Pen Writer's are relatively new, but stable.

Voice Recognition

Summary

Speech recognition technology, the foundation of high-performance speech recognition systems, involves complex statistical models that characterize the properties of sounds, taking into account factors such as male vs. female voices, accents, speaking rate, background noise, etc. The process of speech recognition includes 5 stages: Capture and Digitization; Spectral Representation; Segmentation; Phonetic Modeling; and Search and Match.

Commercial off-the-shelf voice recognition packages recognize spoken words and convert to text for use in other applications. Current state of the art is keyword-based systems that are just now commercially available. Dictionary based systems have improved to the point of high accuracy (some claim 99%).

Audio Mining is a new and growing technology just recently introduced into the voice recognition software and was developed to support Natural Language Processing. Broadcast companies are using audio mining tools to convert, index and classify audio from speeches, presentations and newscasts so that then can be "mined" at a later date so that users can either read or listen to excerpts.

Maturity and Suitability

Dictionary systems are the most mature of the voice recognition technologies and are common and affordable in specialized domains such as medical, legal, construction, etc. Keyword systems that trigger system events or branches in logic have emerging from the research phase and are used in telephone call routing systems. Audio mining is a growing technology that combines both keyword and dictionary techniques. All three of these voice recognition technologies can potentially be applied to this project and will be evaluated further.

Eye/Body Movement Detection

While eye and body movement detection technology has made leaps and bounds over the last few years, affordable and practical devices for human-machine interfaces have not been brought to the commercial market. Research at various universities has suggested that this will be a viable technology in the near future, however, affordability for rural physicians in the next 5 years is doubtful.

One eye tracking system in use at University of Connecticut is a system known as IRIS designed by Reulen et al and manufactured by Skalar Medical, a Dutch company. The recorder exploits the difference in infra-red (IR) reflectance between the iris and the sclera of a healthy eye to detect location of focus. The system employs a horizontal row of nine 950nm IR light emitting diodes (LEDs) to illuminate the iris/scleral boundary on both the nasal and temporal sides of the eye. A corresponding row of nine photo transistors located above the LEDs receives the reflected signal. Transmitter and receiver assemblies for each eye are fitted into a transparent Perspex (or Lucite) case attached to an adjustable lightweight metal head mount. Subtraction of the nasal and temporal detector signals from each assembly gives the eye position with respect to head position.

Natural Language Processing

Natural language processing technology could greatly enhance the conversion of paper-based information to electronic media via spoken words in cases where the information is recorded in sentence form or the users interprets raw data and speaks in complete sentences.

The main aim of linguistic theory is to show how larger units of meaning arise out of the combination of the smaller ones modeled by means of a grammar. Computational linguistics then tries to implement this process in an efficient way usually by subdividing the task into syntax and semantics. Syntax describes how the different formal elements of a textual unit like a sentence can be combined. Semantics describes how the interpretation is calculated. The grammar consists of a lexicon, and rules that syntactically and semantically combine words and phrases into larger phrases and

sentences. Several natural language technology products available today employ annotated phrase-structure grammars, grammars with several hundreds or thousands of rules describing different phrase types. Each of these rules is annotated by features and sometimes also by expressions in a programming language. One difficulty with phrase-structured grammars is that they become difficult to maintain, extend and reuse once they reach a certain size. The resulting systems might be sufficiently efficient for some applications but they lack the speed of processing needed for interactive systems (such as applications involving spoken input) or systems that have to process large volumes of texts (as in machine translation).

Natural-language processing of sentences is complex in two ways: *predictively*, in that not every word is equally likely in every context, and *evidentially*, in that the information carried by a sentence depends on the relationships among the words in the sentence. Depending on the application, one or the other of the two complexities can be the forcing function.

Several organizations are studying and implementing natural language processing technology:

- Microsoft Speech Technology Group
- The Butler Hill Group
- The Computation and Language E-Print Archive
- Linguistic Data Consortium

The ARL team does not envision using natural language processing as part of the final solution since very few of the paper-based medical records have complete sentences.

Information Standards Investigated

The ARL Team evaluated two related healthcare information standards for transmitting information between healthcare systems and for persistently storing and presenting the clinical documents. Both standards are widely adopted in the healthcare industry and both have major revisions nearing completion and adoption.

Health Level 7 (HL7)

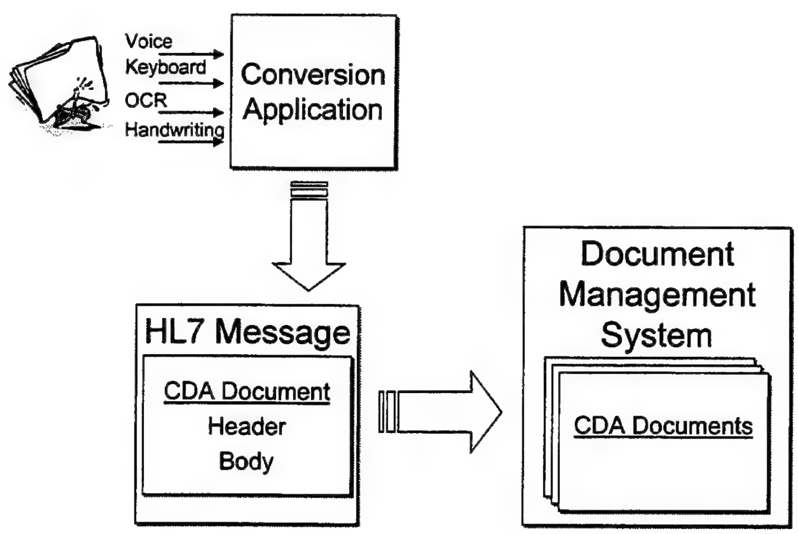
HL7 is a global medical information standard organization with approximately 2000 individual members and 500 corporate members. Currently at version 2.4, HL7 includes standards for transmitting medical information between computerized systems. Version 2.4 messages use ASCII characters to separate fields and to indicate optional and repeatable fields. This was a common approach to system interfaces designed during the 1980s and 1990s. However, the general approach is self-limiting because there is no formal relationship between data elements. As messages become more complex and as interoperability requirements increase individual systems tend to fall behind implementing the latest interface standards and point solutions evolve, thus defeating the intent of the standard.

HL7 version 3, nearing completion and adoption, corrects the limitations of version 2 by creating on overall object model for medical information exchange call the "Reference Information Model", or RIM. The RIM is developed using the Unified Modeling

Language (UML). It consists of 70 classes, all of which are based on 6 backbone classes described on the HL7 web site[1]:

- **Act** - represents the actions that are executed and must be documented as health care is managed and provided;
- **Participation** - expresses the context for an act in terms such as who performed it, for whom it was done, where it was done, etc.;
- **Entity** - represents the physical things and beings that are of interest to, and take part in health care;
- **Role** - establishes the roles that entities play as they participate in health care acts;
- **ActRelationship** - represents the binding of one act to another, such as the relationship between an order for an observation and the observation event as it occurs; and
- **RoleLink** - represents relationships between individual roles.
-

All future HL7 messages and documents will be based on XML schemas derived from the RIM making development, validation and implementation significantly simpler. Refined Message Information Models, called R-MIMs, are derived from the RIM for related groups of messages like "orders". Finally, Hierarchical Message Definitions (HMDs) are developed for the messages themselves.
The ARL team envisions using HL7 standards in two ways. In the near term the team will likely use the HL7 Clinical Document Architecture as the container for the electronic medical record (described below). In the future, and outside the scope of this effort, the team envisions using HL7 messages to transmit the CDA documents like the electronic medical record from transcription/conversion systems to electronic health record information systems and document management systems.



Clinical Document Architecture (CDA)

The Clinical Document Architecture is the standard that ARL Team will use for storing the electronic medical record abstracted from the paper medical records.

[1] HL7 Web Site. http://www.hl7.org/library/

The HL7 web site describes the CDA as:

> "The CDA… provides an exchange model for clinical documents (such as discharge summaries and progress notes)—and brings the healthcare industry closer to the realization of an electronic medical record. The CDA Standard is expected to be published as an ANSI approved standard by the end of the year.
>
> "By leveraging the use of XML, the HL7 Reference Information Model (RIM) and coded vocabularies, the CDA makes documents both machine-readable—so they are easily parsed and processed electronically—and human-readable—so they can be easily retrieved and used by the people who need them. CDA documents can be displayed using XML-aware Web browsers or wireless applications such as cell phones."[2]

Documents developed in accordance with the CDA have the following characteristics:

- "**Persistence** – A clinical document continues to exist in an unaltered state, for a time period defined by local and regulatory requirements.
- **Stewardship** – A clinical document is maintained by a person or organization entrusted with its care.
- **Potential for authentication** - A clinical document is an assemblage of information that is intended to be legally authenticated.
- **Wholeness** - Authentication of a clinical document applies to the whole and does not apply to portions of the document without the full context of the document.
- **Human readability** – A clinical document is human readable."[3]
-

The CDA specification does not specify how to create documents or how to store them in a document management system. Similarly, security, confidentiality and data integrity are not part of the CDA specification. These functions are outside the scope of the specification and are left to individual implementations.

> "A CDA document is comprised of a header and a body. The header identifies and classifies the document and provides information on authentication, the encounter, the patient, and the provider. The purpose of the CDA header is to enable clinical document exchange across and within institutions; facilitate clinical document management; and facilitate compilation of an individual patient's clinical documents into a lifetime electronic patient record. The body contains the clinical report, and is conceptually divided up into body structures, body entries, and external references."[4]

Application developers, like the ARL team, can build CDA templates to create specialized CDA documents such as "discharge summary", "consultation note" or "electronic medical record". Each template can implement its own constraints for the sections in the document (section-level templates) as well as the information recorded within each section (entry-level templates).

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[2] HL7 Web Site. http://www.hl7.org/library/

[3] "HL7 Clinical Document Architecture, Release 2", San Antonio Draft, January 6, 2003.

[4] "HL7 Clinical Document Architecture, Release 2", San Antonio Draft, January 6, 2003.

The XML CDA document is both machine processible and human readable, however, the human readable format is valuable only to technical people. The CDA will usually have an XML stylesheet applied to it before it is presented to medical personnel so that it resembles a word processed document or a web page. The CDA has been designed so that a single stylesheet can be applied to all CDA documents.

Once created, it is sometimes necessary to modify or replace CDA documents. The specification includes attributes to indicate the identification and version number of updated documents.

Summary

The research above reveals that there are very inventive technologies on the horizon for tackling the problem of efficiently converting paper medical records into electronic form. In the near term, however, the combination of keyboard entry, voice recognition, handwriting recognition and optical character recognition can be selectively and affordably combined into a realistic and practical solution for this challenge. No single technology satisfies all the requirements. Once converted, the HL7 and CDA standards are viable for saving and transmitting the electronic medical record.

Appendix B

Armstar Phase II
Patient Record Data Schema

May 15, 2003

Prepared for:	Dianne Emminger Armstrong County Memorial Hospital (ACMH) Chief Information Officer
Contract:	20F20-FFT2002, Task 1.1.2
Prepared by:	Janet Jonson and Bob Walter Penn State University / Applied Research Laboratory (ARL) Applied Enterprise Systems Department

Purpose

An affordable and streamlined process is needed to migrate the critical patient information from legacy, paper-based patient records into an electronic format that is compatible with information technology that can be successfully employed in the rural healthcare delivery system to overcome resource shortages and improve collaboration among service providers.

This document summarizes the information physicians require to be converted from paper-based electronic medical records. The specific task is:

> "Conduct a literature review, focus groups and individual interviews with medical providers (physicians and nurses) and medical administrators to determine the appropriate content of a patient record. The intent should not be so much as to agree upon the ideal patient record as to determine what information is needed to adequately represent a patient record given its transition from paper content to electronic format."

Background

Armstrong County Memorial Hospital (ACMH) provided 40 Primary Care medical records to be converted from paper to an electronic form, to the ARL team. The medical records do not have a consistent structure, order or content and there are several formats for recording the same information, such as allergies. All records have handwritten notes with the expected wide variations in legibility. Many records have ambiguous entries in form fields, such as checkboxes, that are easily resolved by looking at other information on the form.

Approach

Private practice physicians and ACMH physicians were asked to supply their top ten chart extractions. Six physicians of different specialty supplied a list of their top ten chart extractions. From these lists, the ARL team compiled a list to determine the chart extractions that were identified consistently by the physicians and the number of times it appeared in the physician's lists.

Once the information was compiled, physicians, hospital administrators and ARL personnel held a meeting to discuss the compiled information. It was determined from this meeting that the information most frequently requested in their survey responses was not necessarily their top priority. After an hour of discussions, the following patient information categories will need to be captured to create an Electronic Medical Record (EMR):

- Demographics
- Patient Problem History
- Family History
- Social History

- Medications
- Allergies
- Labs
- Radiology
- Cardiology
- Discharge Summary

The related information per above category was determined and an initial source and capture technique were determined. The categories and associated information will be described in Information Priorities section.

Information Priorities

Patient Information Categories

The following chart is a summary of the Top 10 Chart Extractions from the information the physicians provided.

Medical Information Types	# of Physicians Requested
Radiology/X-Ray Reports	7
Labs	5
Meds - Current/Chronic	4
Physician and Nursing Notes	4
Cardiology/EKG	3
Consults	3
ER Records/Notes	3
Patient Demographics/Chart (Physical Characteristics)	3
Allegeries	2
History/Physical	2
Hospitalizations/Hospital Records	2
OR Notes	2
Patient Problem List	2
Physicians Discharge Summary/Notes	2
Referrals	2
Coumadin Flow Sheet	1
Dexa-Scan	1
Lab/Delivery	1
Mammograms	1
Other Studies	1
Pap Smears	1
Past Medical History (PMH)	1
Prescription Reference Data	1
Social History	1

Patient Information Categories

After meeting with the physicians and ACMH administration, patient information categories were determined from the Top 10 Chart Extractions. The following sections provide the description for the different patient information categories as well as the

primary and secondary sources and the primary and secondary techniques for capturing the information in the electronic health record.

Demographics

Data Element	Priority	First Source	Second Source	Primary Capture Technique	Secondary Capture Technique	Data Type
Name		HIS	Practice Mgmt	import	keyboard	text
Address 1,2, city, state, zip		HIS	Practice Mgmt	import	keyboard	text
H phone		HIS	Practice Mgmt	import	keyboard	text
W phone		HIS	Practice Mgmt	import	keyboard	text
M phone		HIS	Practice Mgmt	import	keyboard	text
Marital status		HIS	Practice Mgmt	import	keyboard	text
Sex		HIS	Practice Mgmt	import	keyboard	text
Race		HIS	Practice Mgmt	import	keyboard	text
Religion		HIS	Practice Mgmt	import	keyboard	text
DoB		HIS	Practice Mgmt	import	keyboard	date
Height		HIS	Practice Mgmt	import	keyboard	integer
Weight		HIS	Practice Mgmt	import	keyboard	integer
Insurance						
Policy number		HIS	Practice Mgmt	import	keyboard	text
Group number		HIS	Practice Mgmt	import	keyboard	text
Subscriber name		HIS	Practice Mgmt	import	keyboard	text
Policy effective date		HIS	Practice Mgmt	import	keyboard	date
Relationship to subscriber		HIS	Practice Mgmt	import	keyboard	text
DoB of subscriber		HIS	Practice Mgmt	import	keyboard	date
PCP		HIS	Practice Mgmt	import	keyboard	text
Co-pay		HIS	Practice Mgmt	import	keyboard	integer

Patient Problem History

Data Element	Priority	First Source	Second Source	Primary Capture Technique	Secondary Capture Technique	Data Type
Problem		Chart	Practice Mgmt	voice	keyboard	text
ICD-9 code		Chart	Practice Mgmt	voice	keyboard	text
Comments		Chart	Practice Mgmt	voice	keyboard	text
Onset date		Chart	Practice Mgmt	voice	keyboard	date
Frequency		Chart	Practice Mgmt	voice	keyboard	text
Inactive date		Chart	Practice Mgmt	voice	keyboard	date

Family History

Data element	Priority	First Source	Second Source	Primary Capture Technique	Secondary Capture Technique	Data Type
Relationship		Chart	Practice Mgmt	voice	keyboard	text
Problem		Chart	Practice Mgmt	voice	keyboard	text
Comments		Chart	Practice Mgmt	voice	keyboard	text

Social History

Data element	Priority	First Source	Second Source	Primary Capture Technique	Secondary Capture Technique	Data Type
Alcohol use		Chart	Practice Mgmt	voice	keyboard	text
Tobacco use		Chart	Practice Mgmt	voice	keyboard	text
Drug use		Chart	Practice Mgmt	voice	keyboard	text
Sexual activity		Chart	Practice Mgmt	voice	keyboard	text
Birth control/protection		Chart	Practice Mgmt	voice	keyboard	text

Medications

Data element	Priority	First Source	Second Source	Primary Capture Technique	Secondary Capture Technique	Data Type
Name of medication		Chart	HIS	voice	import	text
Dosage quantity		Chart	HIS	voice	import	text
Dosage frequency		Chart	HIS	voice	import	text
Date started		Chart	HIS	voice	import	date
Date ended		Chart	HIS	voice	import	date
Reason		Chart	HIS	voice	import	text

Allergies

Data element	Priority	First Source	Second Source	Primary Capture Technique	Secondary Capture Technique	Data Type
Agent		Chart	HIS	voice	import	text
Adverse reaction		Chart	HIS	voice	import	text
Date reported		Chart	HIS	voice	import	date
Allergy type (side effect, systemic)		Chart	HIS	voice	import	text

Labs

Data element	Priority	First Source	Second Source	Primary Capture Technique	Secondary Capture Technique	Data Type
Date		Chart	HIS	voice	import	date
Test		Chart	HIS	voice	import	text
Result		Chart	HIS	voice	import	text
Interpretation		Chart	HIS	voice	import	text

Radiology

Data element	Priority	First Source	Second Source	Primary Capture Technique	Secondary Capture Technique	Data Type
Date		Chart	HIS	voice	import	date
Test		Chart	HIS	voice	import	text
Interpretation		Chart	HIS	voice	import	text
Image		HIS		import		image

Cardiology

Data element	Priority	First Source	Second Source	Primary Capture Technique	Secondary Capture Technique	Data Type
Date		Chart	HIS	voice	type	date
EKG Graph		Chart	HIS	scan	import	image
Interpretation		Chart	HIS	voice	type	text

Discharge Summary

Data element	Priority	First Source	Second Source	Primary Capture Technique	Secondary Capture Technique	Data Type
Admission date		HIS	Chart	import	voice	date
Discharge date		HIS	Chart	import	voice	date
Reason for admission		HIS	Chart	import	voice	text
Discharge diagnosis		HIS	Chart	import	voice	text
Services		HIS	Chart	import	voice	text
Summary of findings		HIS	Chart	import	voice	text
DRG data		HIS	Chart	import	voice	text

<u>**Appendix C**</u>

PENNSTATE ARL

Armstar Phase II
Technology Overview

December 5, 2003

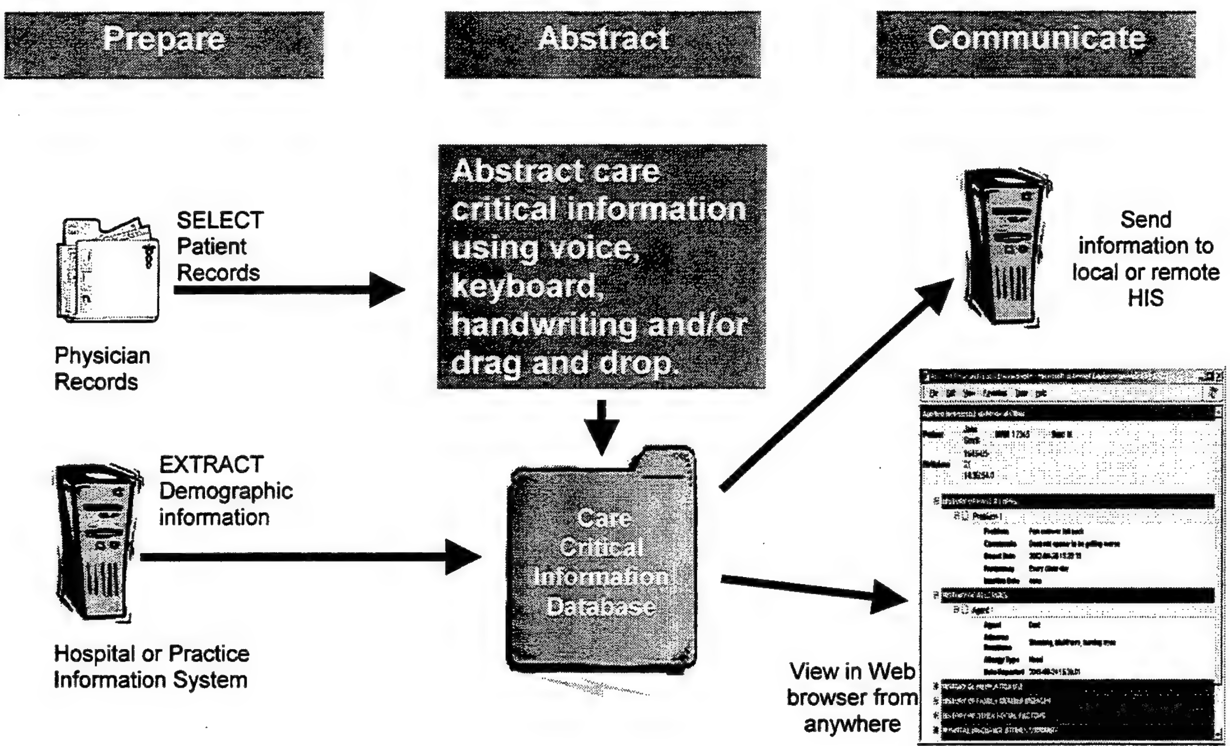
Prepared for:	Dianne Emminger Armstrong County Memorial Hospital Chief Information Officer
Contract:	20F20-FFT2002, Task 1.2.2
Prepared by:	Brandin Claar and Bob Walter Penn State University / Applied Research Laboratory Applied Enterprise Systems Department

Introduction

Physicians need affordable and streamlined process to migrate critical patient information from legacy, paper-based patient records into an electronic format that is compatible with information technology that can be successfully employed in the rural healthcare delivery system to overcome resource shortages and improve collaboration among service providers.

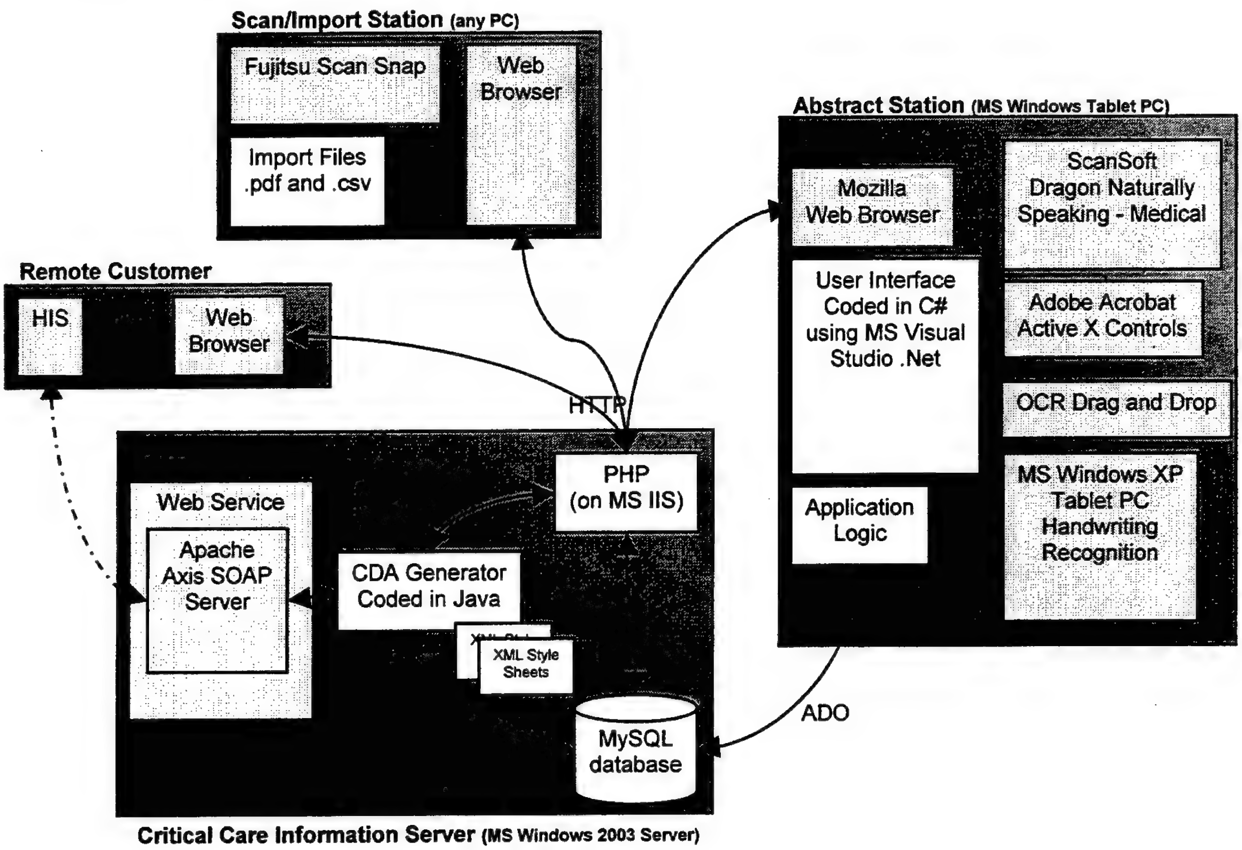
The source documents are scanned into a database as PDF documents and processed using the abstraction tool (henceforth ARMSTAR GUI). Information can also be extracted from existing electronic databases. The abstracted data is then processed into a CDA (Clinical Document Architecture) version 2 document. CDA is a standard of HL7 (http://www.hl7.org). Figure 1 shows an overview of the ARMSTAR system.

Figure 1. ARMSTAR Overview



This document describes the components of the ARMSTAR Care Critical Data Abstraction System, defines their role as part of the overall system, as well as the interactions between components. For the purpose of this document, the components are classified between server (Care Critical Information Server) and client (Abstract Station), although both server and client components can be configured on the same system for standalone usage. Figure 2 shows the different technologies that have been integrated during the course of this project. This figure shows a Scan/Import station. Any PC with access to a high-quality scanner and connectivity to the server could function as a Scan/Import Station, so this part of the architecture is not detailed in this document.

Figure 2. ARMSTAR Technologies



Care Critical Information Server

Overview

The Care Critical Information Server has several roles. It provides a centralized resource for importing and maintaining patient records as they are transformed into CDA documents. It contains the database server that is the persistent store for imported documents, raw abstracted data, and patient records in the CDA format. It also provides the capability to serve patient records to remote users.

MySQL Database

The MySQL database is the persistent store for patient data. Table 1 shows the tables and fields of the database. Columns labeled in bold are keys. The first column for a particular table is the primary key. All tables use "patient_id" as a key. This makes it possible to gather all knowledge of a particular patient with a single key. Some tables use "entry_id" also. This key serves to identify individual data entries under a particular category and link

them to the "images" table. The "images" table allows image data to be associated with any table or entry in the database. the same table. It can store multiple images for a particular entry. This flexibility is achieved by using the "image_id" and "tablename" columns in addition to the standard keys used elsewhere.

Table 1. ARMSTAR Database

Column	Data Type
Table Name: demographics	
patient_id	System.Int32
First_name	System.String
Last_name	System.String
address_1	System.String
address_2	System.String
City	System.String
State	System.String
Zip	System.String
home_phone	System.String
work_phone	System.String
mobile_phone	System.String
marital_status	System.String
Sex	System.String
Race	System.String
religion	System.String
Dob	System.String
Height	System.String
weight	System.String
Table Name: insurance	
patient_id	System.Int32
policy_number	System.Int32
group_number	System.String
subscriber_name	System.String
policy_effective_date	System.String
relationship_to_subscriber	System.String
Dob_of_subscriber	System.String

Pcp	System.String
co_pay	System.Int32
Table Name: allergies	
entry_id	System.Int32
patient_id	System.Int32
Agent	System.String
Adverse_reaction	System.String
date_reported	System.String
Allergy_type	System.String
Table Name: cardiology	
entry_id	System.Int32
patient_id	System.Int32
Date	System.String
interpretation	System.String
Table Name: discharge_summary	
entry_id	System.Int32
patient_id	System.Int32
admission_date	System.String
discharge_date	System.String
reason_for_admission	System.String
discharge_diagnosis	System.String
services	System.String
Summary_of_findings	System.String
Drg_data	System.String
Table Name: family_history	
entry_id	System.Int32
patient_id	System.Int32
relationship	System.String
Problem	System.String
comments	System.String
Table Name: images	
image_id	System.Int32
patient_id	System.Int32
tablename	System.String
entry_id	System.Int32

description	System.String
filename	System.String
thumbnail	System.Drawing.Bitmap
full_image	System.Drawing.Bitmap
Table Name: immunizations	
entry_id	System.Int32
patient_id	System.Int32
date	System.String
name	System.String
Age	System.String
comments	System.String
Table Name: labs	
entry_id	System.Int32
patient_id	System.Int32
Date	System.String
Test	System.String
Result	System.String
interpretation	System.String
Table Name: medications	
entry_id	System.Int32
patient_id	System.Int32
name	System.String
dosage_quantity	System.String
dosage_frequency	System.String
date_started	System.String
date_ended	System.String
Reason	System.String
Table Name: patient_history	
entry_id	System.Int32
patient_id	System.Int32
Problem	System.String
Icd9_code	System.String
Comments	System.String
onset_date	System.String
Frequency	System.String

inactive_date	System.String
Table Name: radiology	
entry_id	System.Int32
patient_id	System.Int32
Date	System.String
Test	System.String
interpretation	System.String
Table Name: social_history	
entry_id	System.Int32
patient_id	System.Int32
Alcohol_use	System.String
Tobacco_use	System.String
drug_use	System.String
sexual_activity	System.String
birth_control_protection	System.String

IIS/PHP Server

Microsoft's IIS (Internet Information Server) is used to provide a web interface to the Care Critical Information Server. PHP is used to provide dynamic access to the database resources. PHP is a popular language for developing web applications. It allows rapid development of web interfaces to SQL database systems such as MySQL. By using PHP, we were able to develop a rudimentary interface for developing and testing the CDA Generator while the ARMSTAR client was still in its infancy.

Java CDA Generator

The Java CDA Generator, when requested, retrieves a patient's data from the MySQL database and generates an XML document directly from the database. This document is then processed by a stylesheet to produce a human-readable document. This document is usually in the form of HTML. The HTML document can be viewed via the web interface or from the client. The Clinical Document Architecture, Version 2, leverages the rich object-oriented data model of the HL7 Version 3 standard. We chose to implement our CDA Generator using Java technology because HL7 is producing their own reference implementation of the HL7 Version 3 standard in Java. The current ARMSTAR Java CDA Generator does not make use of the HL7 code, but the use of Java here should make a potential future integration much smoother.

Abstract Station

Overview

Various data collection methods were evaluated as the GUI was designed and tested. Table 2 provides a summary of the comparison. To provide an efficient environment for data collection and abstraction, the following assumption was made:

> *The GUI will give the user the flexibility to decide the appropriate tradeoff between the speed of data collection and detail of data abstraction. A provider organization may develop guidelines for collection and abstraction, but the application will not attempt to implement such guidelines beyond the database schema.*

There are 2 motivations for making this assumption. First, programming the application with the knowledge to implement data collection guidelines would be exceedingly difficult. Second, doing so would only restrict the flexibility of the application. Having this flexibility means the user will have the ability to use any data collection method at any point in the application. It is the user's responsibility to choose a collection method which is suitable to how the data is likely to be used in the future. For example, if medication information is collected using image capture, a future database search for a certain type of medication would probably not be able to find the medication if it was contained within image data. However, the data would still display in a human-readable representation of the CDA.

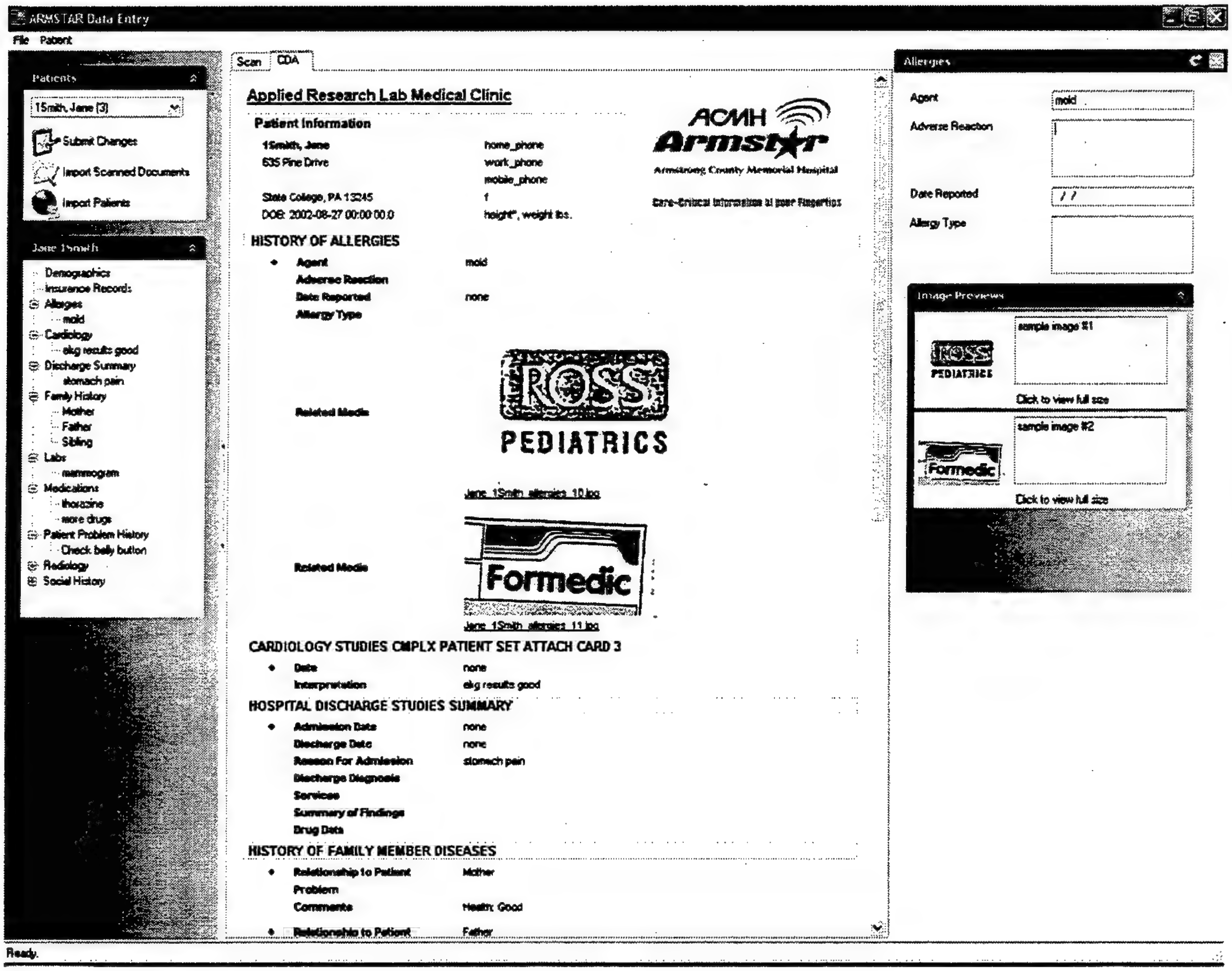
The data collection methods are summarized in the following table:

Table 2. ARMSTAR Data Collection Methods

Types	Status	Pros	Cons	Preliminary Recommendations
Keyboard and mouse	Ready	Great for transcriptionists.		Continue to refine. Need to add shortcut keys.
Voice	In progress	Nice for reading long hand written text. OK for hands free navigation.	A good transcriptionist can probably move faster with keyboard and mouse.	Continue to refine. Customer feedback will dictate its future.
Handwriting	Integrated	OK in tablet only environment.	Slowest entry method.	Only valuable in very mobile environment or for keyboard novices.
OCR	Ready	Works well on clean text	Current tool doesn't handle crooked text or blurry copies.	Keep it. Big time saver.
Image capture	Ready	Works well.		Keep it. Good for keeping historical record of relevant images.

The ARMSTAR GUI is divided into 3 main panels: an explorer bar to the left, a tabbed panel in the center, and a data entry panel to the right. Figure 3 is a screenshot of the application.

Figure 3. ARMSTAR GUI



Explorer Bar

The explorer bar provides navigation controls for selecting, importing, and submitting patient data. It also contains the "tree view" of the data. The top level of the tree shows the main categories of data collection. These categories correspond to tables in the database. Some of these categories can contain child nodes known as entries. The entries correspond to database rows distinguished by the "entry_id" key. New entries can be added by right-clicking on the tree view.

Tab Panel

The tab panel allows the user to switch between the "Scan" tab and the "CDA" tab. The "Scan" tab uses the Adobe Acrobat ActiveX control to display scanned documents which have been imported into the database. This allows the user to navigate imported paper

documents and use them as a source for image capture or OCR. The "CDA" tab allows the user to view output directly from the CDA generator. This allows the user to verify the final disposition of the data.

Voice Recognition and Medical Dictionary

Scansoft's Dragon Naturally Speaking 7 Medical Solutions system is integrated into the Abstract Station as an ActiveX control. This system provides voice commanding and navigation of the GUI as well as voice-based data entry. Data entry capability is augmented by the use of an extensive medical dictionary which gives the system a very high level of accuracy when recognizing medical terminology. The ARMSTAR client dynamically configures *Naturally Speaking* with voice commands. This allows the user navigate all data entry screens and fields hands-free. *Naturally Speaking* includes a sophisticated system for editing text. A key feature is the ability to select erroneous words and replace them from a drop-down menu of likely substitutions.

For best results, the user needs to perform training with the *Naturally Speaking* product before using the ARMSTAR system. During training, *Naturally Speaking* does an audio quality test to confirm that the audio input device is capable of capturing sufficient quality audio. The program includes texts with varying difficulty levels for the training process. The user selects a passage from those provided and reads the text in short blocks, a task which consumes about 15 minutes. The user may then provide sample texts such as emails or other documents for the system to become acclimated to a particular style of writing. These additional texts can also be used for further voice training. Depending on the speed of the computer the entire process may take between 25 and 45 minutes.

Optical Character Recognition

The ARMSTAR GUI also contains an OCR (Optical Character Recognition) component. The tool is a part of ISI Toolbox from Image Solutions, Inc. It works as a plug-in for the Acrobat ActiveX control. The OCR component allows typed text which was scanned into the source document to be quickly converted into machine-readable text. As opposed to scanned data, which is graphical, machine-readable text can be searched or processed by computers. This will allow better abstraction of the data.

4. Conclusion

While it is obviously desirable that all of the information in a patient's file be quickly stored in an easily searchable electronic format, this is an unrealistic goal given the constraints of designing an efficient, low-cost system. Instead, the ARMSTAR system provides a flexible framework with several options for collection and abstraction. Inherent in this design is the assumption that the user will be able to determine the appropriate balance between collection speed and detail of abstraction. Fortunately, as a target data format, the CDA specification was designed with the flexibility to make this system possible. Plus, it allows the data to be imported as an electronic record into other Health Information Systems.

Appendix E

Excerpts from

PACS Project
Prepared for
Armstrong County Memorial Hospital

Prepared by
Dale Hunt
The Thomas Group, Ltd.
130 Chaparral Court, Suite 200
Anaheim, CA 92808

What is PACS?

The acronym "PACS" stands for Picture Archive Communication System. [Historically], the pictures, or images, taken in a radiology department are put on film. State and Federal laws require that these films be kept for a minimum of five years unless it is a pediatric or mammography study. Pediatrics must be kept for five years after the patient turns `18, and mammography must be stored for 15 years. These laws create a necessity for massive storage space. In order for a referring physician to view images, they must either check out original films or visit the film library. Film presents other difficulties as well, including: material expense, long turnaround time, damaged or lost studies, and an inability to adapt to the changing technological environment. PACS eliminates the need for massive storage space and the difficulties inherent in film usage.

Currently, within [ACMH] radiology services, computers are used to create images in CT, MRI, ultrasound, nuclear medicine and digital radiography. These modalities convert a digital image to film. PACS utilizes computer technology to capture, store, manipulate and send digital images instead of using film. For digital modalities, PACS simply captures the image from the devices's computer and stores it in the PACS computer, instead of converting it to film. The digital images are then stored in a master archive where the images are accessible for viewing. The images may be viewed at any designated review station connected to the PACS or hospital network. The images may be transferred outside the hospital using telephone communications via POTS, ISDN, T1 or T3 using Web technology.

For the non-digital modalities, such as x-ray systems, or x-ray and fluoroscopy systems (analog modalities), the images need to be converted to a digital format. This can be accomplished using three different methods. The first, and most popular method being used today is Computed Radiography (CR). This method uses phosphorus plates that look like regular film cassettes to capture digital information by exposing the phosphorus to radiation, then using a computer to create the image using that digital information.

Efficiency Gains

PACS will not only achieve … cost savings … it will drastically improve the efficiency of the radiology department.

Eliot L. Siegel, MD describes the effects of PACS on Boston VA Medical Center in "The Benefits of Filmless Radiology" He cites a study performed at the Boston VA Medical Center regarding the effect of PACS on their Radiology department, specifically on CT technicians. What they found was that the time for a technologist to complete a CT exam was decreased by 50% to 60%. The time for the radiologist to read the CT exam was decreased by approximately 15% with an overall decrease of 8%-12% noted. The results discussed by Dr. Siegel are not a-typical.

In addition to decreased time to read the exam, most facilities see a significant reduction in turnaround time for images. This can be especially important in STAT cases. Instead of

waiting for the traditional filmed exam to follow its natural course from the modality to the radiologist to the primary physician or specialist, PACS allows the images to be available immediately on the hospital network. At Boston VA Medical Center, Dr. Siegel notes that a voice report is available in 5 to 10 minutes while a transcribed report is posted to the hospital information system (HIS) in one to two hours. This increased efficiency has been credited with reducing the length of time a patient stays in the hospital or emergency room, improving the quality of patient care, and increasing physician referrals.

Another issue often experienced in radiology departments is that of lost or rejected studies, resulting in lost revenue, reduction in patient satisfaction, increase in turnaround time to the referring physician and many other concerns. Lost films are inherent to hard copy due to the fact that they can only be in one place at a time. PACS solves that issue by allowing soft copy distribution to several places at a time. Additionally, PACS stores the image in a digital archive. Boston VA Medical Center sites a 7.9% decrease in the incidence of lost film since PACS implementation.

Rejected studies are also reduced with PACS. The incidence of poor image capture technique is significantly reduced. This is due to the image correction tools available in PACS, as well as the ability to view the image on computer screens prior to printing the film. Image rejection rates were reduced from 5% to 0.8% at Boston VA Medical Center with their PACS implementation.

Another benefit of PACS is the ability to sustain a sudden growth without a decrease in quality of care or an increase in staffing levels. "Early Adopter Adapts" discusses the challenges faced by Boston VA Hospital when they initially adopted PACS, and when they merged with two other Massachusetts VA hospitals and assorted clinics to form the VA Boston Healthcare System. The merger required that Boston VA upgrade to faster computers due to the increase in exam volumes and the article quotes M. Elon Gale, MD of Boston VA Hospital as saying:

> *Before PACS, all of these sites taken as a whole employed about 25 radiologists; now the number is around 15. In part, we had 25 because our operating budgets were more generous in those days and we could afford to staff like that. But mainly, we had 25 because we needed 25. Now we are able to accomplish an equivalent workload thanks to PACS and its potent economies of scale.*

Cape Fear Valley Medical Center performed a study regarding the length of stay pre- and post-PACS. "PACS Credited With Cutting Length of Stay By Over A Day in 3 ICU Units" describes the results of the study. Although there was no proof that PACS was the cause of the length of stay reduction, staff could not point out to any other explanation. The rapid turnaround of exams allowed for better assessment of patients, making a difference in the outcome of ICU patients.

Appendix F

Armstrong County Memorial Hospital

Armstar Phase II

Position Paper Regarding Protection of Personal Health Information

Prepared by
Dianne Emminger
Vice President Information Services
Armstrong County Memorial Hospital

Definitions:

Access	Access to patient information is addressed in several hospital policies and medical staff rules and regulations. In summary, those policies dictate that confidential patient information be made accessible only to those employees/staff members who are involved in the care of the patient, the management of the records, the billing for patient services, and to others on a need-to-know basis (i.e. quality review or resource utilization.)
Security	ACMH utilizes physical security combined with several layers of logical security systems to restrict access to confidential information that is stored electronically.

Network security:

The network is segmented into several smaller networks, which serve to separate the types of information being stored. For example, patient information resides on a different segment than Internet or archives of policies and procedures. One of the computer systems on the network, the access server, is programmed to make the determination of which users can access servers on any segment of the network.

- Computers on the backbone are given special addresses to gain access.
- Dial-up users located in off-campus physician's offices utilize a process wherein they dial into the system and the system calls them back – verifying the location of the user.
- Remote users that desire access to the network via high-speed Internet connections utilize a combination of a virtual private network (VPN), data encryption, specific addressing schemes, and secure id devices (key fobs.)
- Network-to-network connectivity is accomplished using intelligent routers.

In all of the above access methods, the user still needs a password. Internet "hackers" are blocked from the network by a firewall and entry attempts are logged and reviewed by our network administrator.

Application Security:

Once the user has cleared the network access systems and has entered our network he needs yet another password to access the specific computer hosting the application. Within the application itself, our systems restrict the specific

information the user may see—i.e., patient demographic information, clinical information, or business information. The following specifications have been developed for the acquisition of new systems.

User defined passwords
Forced password changes within set periods of time
Passwords must be a certain length
Systems must deny access after a defined number of incorrect attempts
Systems must automatically log back or off after a defined period of time and require a password for re-entry
Systems must log all access to confidential information, including read only, identifying the user.
Data encryption on the server

Mitigation of Risks:

People can make mistakes – wrong patient – wrong information. Programs may contain "bugs" and fail to operate as specified. Downtime interrupts the constant flow of information collection and recovery systems may fail to identify missing information.

These risks however are mitigated by some of the features modern information technology can provide. Well-programmed computer applications actually provide tools to identify errors and improve information integrity. All technology purchased with federal funds and used to process live data is purchased from reputable companies with proven track records. We have engineered redundancy into our systems so that there is no single point of failure. Disaster recovery plans have been created to provide mechanisms to ensure that all data collected during down times are entered into the system. Backup tapes are kept in a secure location remote to the main processing site. "Hot-site" and mobile back-up processing capacity is assured through a contract with Sunguard Recovery Services and funded by ACMH.

Transmission Modes:

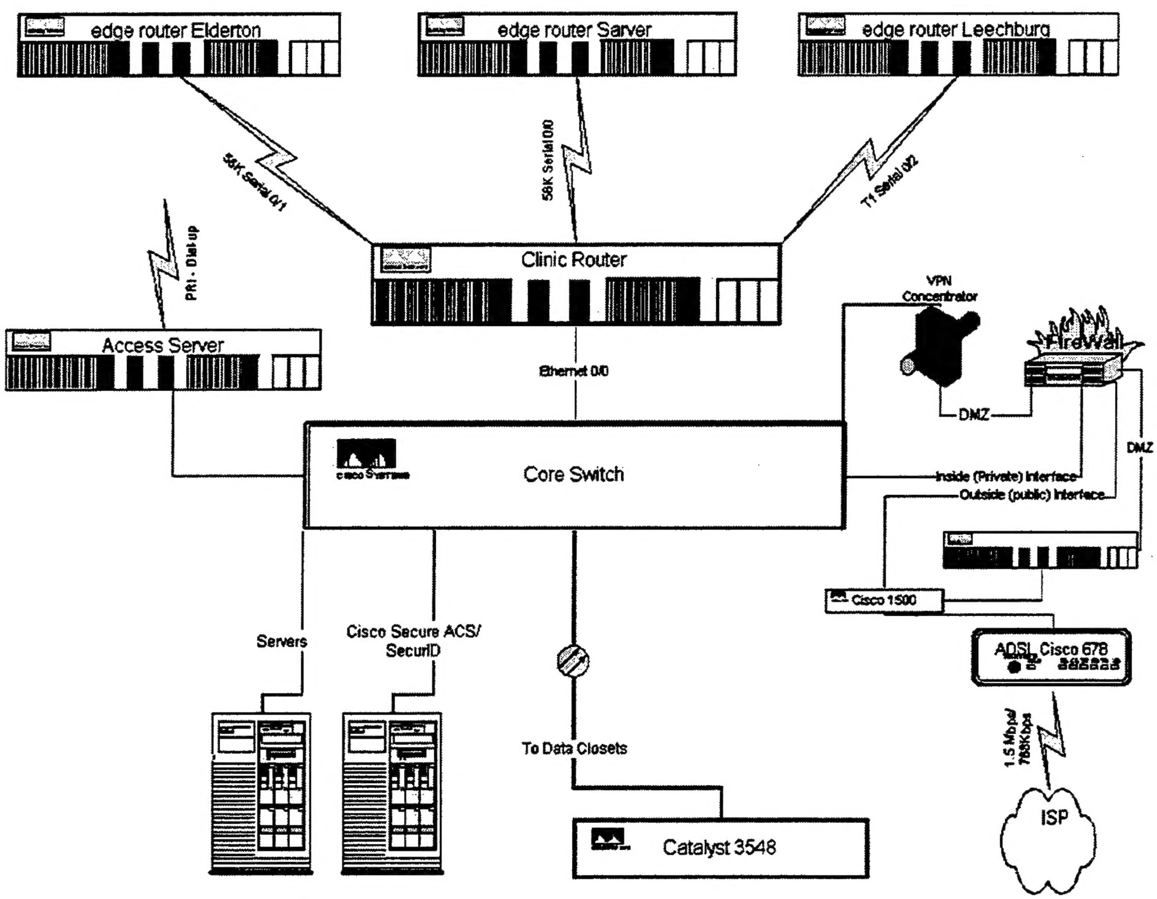
Dial-up access over POTS: network access is controlled by a combination of caller-ID and passwords. Access to data is controlled through authentication to the Citrix Server and authentication to the Meditech EMR. When Caller-ID is not available, the user will be identified via user name and Secure ID password.

Internet access using proprietary VPN and Secure ID software: the user is identified by: VPN Client Secure, user name, and Secure ID password. Network and EMR authentication are controlled through the Citrix application server and the Meditech Server. Dedicated high-speed connection: access is controlled through the Citrix application server and the Meditech EMR server.

Appendix G

Armstrong County Memorial Hospital
Armstar Network Schematic

Prepared by Thomas Admason, Director of Network Technology



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